SEISMIC-HAZARD SCENARIO FOR A M_W 7 EARTHQUAKE ALONG THE SALT LAKE CITY SEGMENT OF THE WASATCH FAULT ZONE, UTAH

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Investigations Undertaken

The Wasatch fault zone parallels the densely populated Wasatch Front area of Utah. The high seismic hazard of the area associated with potential large earthquakes on the Wasatch fault zone has long been recognized. The Salt Lake City segment is one of the more active segments of the Wasatch fault zone (figure 1), generating four surface-faulting earthquakes in the last 6,000 years (Black and others, 1996). A conservative estimate for the magnitude of a surface-faulting earthquake on this segment is moment magnitude (M_W) 7. A large earthquake within the Wasatch Front region would place more than 1.3 million people (1990 census) at risk and cause exceptionally large losses to personal property and infrastructure.

Emergency managers and planners need an accurate and current scenario of expected geologic effects that will likely occur during a large earthquake to plan response and recovery operations. We will take advantage of recent progress in hazard mapping of the Salt Lake City metropolitan area to analyze and map seismic hazards in the Wasatch Front resulting from a M_W 7 event along the Salt Lake City segment of the Wasatch fault zone. Our seismic-hazard maps, at a scale of 1:250,000, will serve as the basis for developing a scenario that can be used to estimate losses using risk-assessment methodology developed jointly by the Federal Emergency Management Agency and the National Institute of Building Sciences, referred to as HAZUS (National Institute of Building Sciences, 1997).

<u>Ground shaking:</u> We will use data on seismic site response, near-field effects, and seismic attenuation to develop earthquake scenario maps of the ground-shaking hazard in the study area. The maps will display peak horizontal acceleration and spectral acceleration at several periods, contoured at intervals of 0.02g. To produce our maps, we will supplement ground-shaking maps of the Salt Lake City metropolitan area produced for an ongoing NEHRP-supported study by URS Greiner Woodward Clyde Federal Services, the Utah Geological Survey (UGS), Pacific Engineering & Analysis, and the University of Utah Seismograph Stations, with new mapping of the remainder of the study area by URS Greiner Woodward Clyde Federal Services and Pacific Engineering & Analysis, using the same methods. Our ground-shaking maps will be deterministic, at a relatively small scale, and will consider geologic site effects using recent data.

Seismic site-response maps are necessary to develop accurate ground-shaking maps. We will supplement a seismic site-response map of the Salt Lake City metropolitan area (Ashland and Rollins, 1999) with new, but less detailed, site-response mapping of the remainder of the study area.

A limited amount of empirical observations (Abrahamson and Silva, 1997) and numerical modeling results (Wong and Silva, 1993; Wong and others, 1995) suggest that near-field effects such as rupture directivity and hanging-wall effects may be significant in the study area. Such effects will be incorporated into the calculated ground motions using the finite-fault approach. We will also incorporate such effects into the ground-motion calculations by employing empirical attenuation relations that account for these effects or by correcting other empirical attenuation relations.

Most attenuation relations were developed by performing regression analyses on data recorded principally in the compressional regime of California. Thus, such relations (Boore and others, 1993; Campbell, 1996) may not be appropriate for the extensional regime of Utah. In our study, a recent relation by Spudich and others (1997) for extensional earthquakes and other relations developed for work on the Yucca Mountain project will also be included in the analysis. To compensate for the possible lack of applicability of empirical relations to our study area, a finite-fault version of the stochastic ground-motion-modeling technique will also be used to compute ground motions on rock. The horizontal accelerations for rock will be multiplied by amplification factors to arrive at values at the ground surface (Wong and others, 1998).

Surface fault rupture: A magnitude 7 earthquake on the Salt Lake City segment of the Wasatch fault zone is expected to be accompanied by rupture of the surface along at least the segment itself (figure 1). Rupture may also overlap onto the adjacent Weber segment to the north and Provo segment to the south, and may occur on the West Valley fault zone, a possible antithetic fault zone west of the Wasatch fault zone in the northern Salt Lake Valley. The main rupture may displace the surface by a few meters, with the west side moving down relative to the east on the Wasatch fault zone and with the relative movement reversed on the West Valley fault zone. The height of the scarp formed will vary considerably along the fault. Surface fault rupture will be accompanied by a zone of deformation a few hundred meters wide on the downdropped side of faults. This zone may include secondary ground cracking, antithetic faulting, graben formation, and tilting of the ground surface.

We will compile a map of the surface fault rupture from detailed published maps of the Wasatch (Machette, 1992; Personius and Scott, 1992; Nelson and Personius, 1993) and West Valley (Keaton and Currey, 1993; Keaton and others, 1993) fault zones. We will map existing traces of the fault zones in the study area, and will map an adjacent zone in which surface fault rupture and associated deformation will likely be confined.

Flooding: Seismically induced flooding may result from lake or reservoir seiches, surface-drainage disruptions, dam failure, or increased ground-water discharge.

No studies of earthquake-induced seiches have been made in Utah. Seiches were reported along the southern shoreline of Great Salt Lake during the 1909 Hansel Valley earthquake (magnitude 6) (Williams and Tapper, 1953). Assuming lake and trestle elevation records and reports of the seiche are accurate, the seiche was more than 4 meters high (Lowe, 1993). We will use this occurrence as an approximation of the potential magnitude of a seiche-related flood hazard near Great Salt Lake and map a hazard around the lake below an elevation of 4 meters greater than a specified lake level following tectonic subsidence.

Rapid increases in ground-water discharge at existing springs, and formation of new springs, commonly accompany large earthquakes. These increases in spring flow may cause local flooding around springs and along streams into which they discharge. Increased spring flow on valley floors could result in ponded water and basement flooding. We will map the location of existing springs as an approximation of the potential for increased ground-water discharge.

Tectonic subsidence: Valley bottoms may tilt toward the Wasatch fault zone on the downdropped side of the surface fault rupture during a large earthquake. As a result, areas along the shores of Great Salt Lake may permanently subside, causing local flooding. Inundation potential depends on lake levels at the time subsidence occurs. Keaton (1986) mapped the inundation potential along the shores of Great Salt Lake for various lake levels that may reasonably be assumed to exist during the next 100 years. We will use these maps for our earthquake scenario. Subsidence may also cause ground-water levels to rise, causing water to pond, and flooding basements and buried facilities. Keaton (1986) mapped areas of possible shallow ground-water flooding from tectonic subsidence, and we will use this map.

Liquefaction: Liquefaction potential was mapped in our study area by Anderson and others (1994a, 1994b, 1994c, 1994d) using the method of Seed and others (1977) combined with SPT and cone-penetrometer data to map the critical acceleration required to initiate liquefaction. Youd and Perkins (1987) developed the Liquefaction Severity Index (LSI) which quantifies the maximum liquefaction-induced ground-failure displacement as a function of earthquake magnitude and distance. Mabey and Youd (1989) developed an LSI relation for Utah to calculate LSI based on earthquake magnitude and distance from the source. We will combine the published liquefaction potential maps with our map of peak acceleration and map maximum liquefaction-induced ground-failure displacement using the LSI relation or other relationships presently being developed under another NEHRP grant (grant award no. 1434-HQ-98-GR-0024) to produce hazard maps for Cache Valley, northern Utah. Where necessary, we will also use the empirical technique of Bartlett and Youd (1992) to extend the liquefaction susceptibility map to areas at the edges of our study area not covered by the liquefaction potential maps, and to confirm levels of displacement estimated by our map by evaluating selected borehole data throughout the study area.

Slope failure: Existing landslides are assumed to have the potential for renewed slope failure during the scenario earthquake. However, additional slopes will also be susceptible to failure, depending upon lithology and slope gradient. Harty (1991) maps landslides and lists geologic formations in Utah commonly involved in landsliding. We will map these formations within the study area; slopes underlain by these formations are assumed to be susceptible to seismically induced landsliding.

Slopes susceptible to landsliding, defined by pre-existing landslide deposits, lithology, and slope gradient, have differing potentials for failure during an earthquake. The potential for slope failure will depend upon earthquake magnitude, source distance, and seismic shaking severity. Wilson and Keefer (1985) compiled these parameters from earthquake-induced landslides generated by 42 historical earthquakes. They established a relationship between the parameters that can be used to derive a probabilistic estimate of the source distance from a given earthquake at which landsliding will occur. Wilson and Keefer (1985) derived separate relationships for coherent landslides and for rock falls. We will use these relations or other relationships presently being developed under our Cache Valley NEHRP grant to map an outer limit of coherent landslides and rock falls on susceptible slopes during the scenario earthquake, and an inner limit within which most coherent landslides and rock falls will occur.

Results

Hazard analysis is not yet underway. The final product generated from this project will be a folio of scenario seismic-hazard maps of areas adjacent to the Salt Lake City segment of the Wasatch fault zone, with accompanying text. The maps will be at a scale of 1:250,000 showing earthquake-related site response, ground shaking, surface fault rupture, and areas of potential flooding, tectonic subsidence, liquefaction, and slope failure. The accompanying text will include discussions of the methods used and conclusions drawn, geotechnical and geological descriptions of map units, and appendices with geotechnical and geological data used in the analyses. The discussion of methods will document GIS protocols and will serve as a model for UGS personnel engaged in future production of earthquake scenario maps. Ultimately, the maps will provide the basis to estimate losses using HAZUS.

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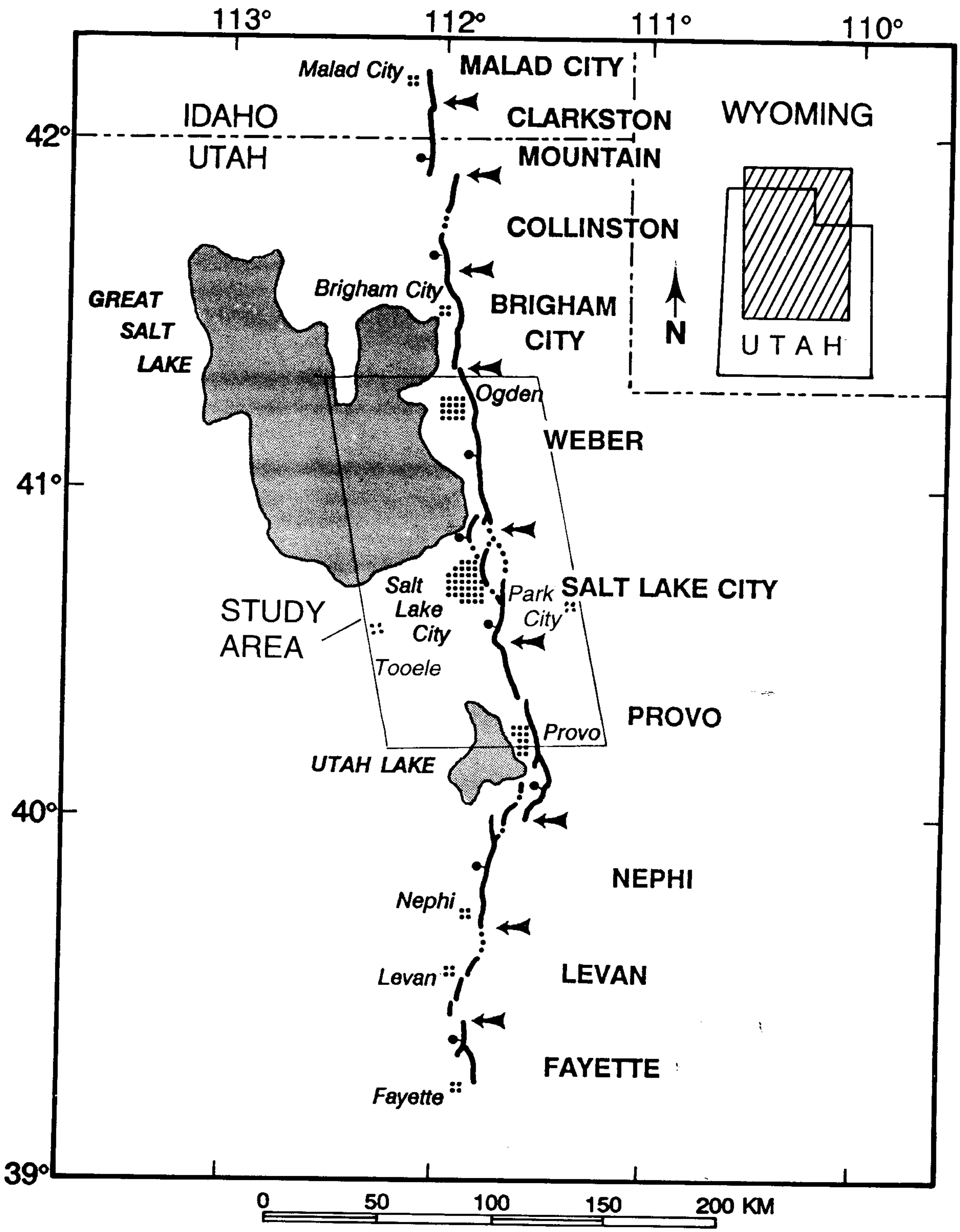
Reports Published

No reports have been published yet, although we intend to present study results at the Sixth International Conference on Seismic Zonation in November 2000. Upon project completion, the Utah Geological Survey will publish the hazard maps and mapping protocols.

Availability of Data

When complete, the database of geotechnical information and seismic-hazard maps will be made available for distribution in digital form by the Utah Geological Survey. The digitized maps will also be available from the State Geographic Information Database through the Utah Automated Geographic Reference Center.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Non-Technical Summary

A large earthquake on the active Wasatch fault zone may impact the lives of more than 1.3 million people living along the densely populated and rapidly expanding Wasatch Front urban area of northern Utah. We will map earthquake hazards such as ground shaking, surface faulting, flooding, landslides, and liquefaction resulting from a large earthquake on the Wasatch fault zone in this region. The maps will be used for emergency-response planning to identify potential earthquake effects and to estimate losses using risk-assessment methodology (HAZUS) developed jointly by the Federal Emergency Management Agency and the National Institute of Building Sciences.